Chandra X-Ray Center

Grating Data Products: Level 2 to CXC Archive Interface Control Document

(http://hea-www.harvard.edu/asclocal/icd/TBD)[1]

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[1]Current DRAFT version can be found at: `http://space.mit.edu/ASC/docs/ICD_TGL2.ps.gz`.
The top-level ICD index is at `http://hea-www.harvard.edu/asclocal/sds/development/ICD/index.html`

Document and Change Control Log

Date	Version	Section	Status
23 Apr 98	0.0	all	Initial Draft, for review by J.Houck
4 May 98	1.0	all	Update for review
8 July 98	1.1	all	Update for release; ARF deleted from Type II PHA file. Type II PHA header refined. Added spectral measurement products.
9 August 98	1.2	4.2, 4.5	Small changes to column specifications; new rows in REGION extension to describe background.
22 October 98	1.2(DRAFT)		Added changebars. Updated unresolved issues (pending changes).
11,26 February 99	1.3	all	– Added language to support Type I PHA. – Added GTI HDU to PHA files. – Removed arf, rmf products: they have separate ICD. – Deleted ARF section; redundant w/ ExpMap ICD. – Removed summary products: TBS by USG in another ICD?
28 May 99	1.3	all	Misc edits for release. CO#'s: 0017–0024,
11 April 2006	2.0	all	Major update; remove obsolete sections; add new content to describe actual format, and changes to be introduced in CIAO4 with tgextract2.
26 July 2006	2.1	all	Changed names of background columns to conform to `dmextract` names. Added TG_R as optional column in region file.
31 August 2006	2.2	4	Changed names of background columns (again) to conform to `dmextract` names. Supercedes (unimplemented) 2.1. (specifically: BACKSCALE change meaning, BBACKSCAL rename to BG_AREA, SBACKSCAL becomes BACKSCALE, SBACKSCAL deleted.)

Unresolved Issues

The following is a list of unresolved, un-reviewed, or un-implemented items:

1. none.

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1 Introduction

This document describes the interface to be employed in transferring the products of grating (HETG, the High Energy Transmission Grating, or LETG, the Low Energy Transmission Grating) obervations Standard Data Processing from the CXC Level 2 processing pipeline to the CXC Data Archive, according to the requirements stipulated in the "ASC Data System Requirements" (Applicable Document 2). The file format defined is also that output by the CIAO tool, `tgextract` (used in the pipeline), which is being enhanced for CIAO 4 (`tgextract2`).

1.1 Purpose

TG (generically referring to HETG and LETG Transmission Grating instruments) Level 2 processing, described in Applicable Document 2, consists of processing TG Level 1.5 or Level 2 event files and ancillary products (which are described in Applicable Document 7) into a binned spectral FITS file. This document describes the structure and content of the resulting files.

1.2 Scope

This interface shall apply to all TG-specific data products that are generated by CXC Level 2 pipelines (or by `tgextract` and distributed to the CXC Data Archive (see Applicable Document 2 and the "ASC Data System Software Design," Applicable Document 3) during the course of the Chandra mission.

1.3 Applicable Documents

The Applicable Documents required for background and detail on grating Level 2 products are as follows:

1. ASC Coordinates: Rev 5.0
   `http://hea-www.harvard.edu/asclocal/sds/docs/jcmdocs/ps/SDS02.ps`

2. ASC AMO-2400 (SE03)
   ASC Data System Requirements (ASC.302.93.0008)

3. ASC AMO-2401 (DS01)
   ASC Data System Software Design (ASC.500.93.0006)

4. ASC FITS File Designers' Guide (ASC-FITS-2.0.0)
   `http://hea-www.harvard.edu/~arots/asc/fits/ascfits.ps`

5. Level 1 to CXC Archive Interface Control Document (Rev. 1.6)
   `http://hea-www.harvard.edu/asclocal/icd/HRC_Level1/hrcl1icd_16.ps`

6. ACIS Data Products:
   Level 1 to ASC Archive Interface Control Document (Rev. 1.9)
   `http://hea-www.harvard.edu/asclocal/icd/ACIS_Level1/acis_l1_1.9.ps`

7. Grating Data Products:
   Level 1.5 to CXC Archive Interface Control Document
   `http://space.mit.edu/ASC/docs/ICD_L1.5.ps.gz`

8. Guide to AXAF Data Products (content.txt; v 2.1), section "FITS File Naming Convention for the AXAF Archive"
`http://hea-www.harvard.edu/~arots/asc/fits/content.txt`

9. FITS REGION Binary Table Design (ASC-FITS-REGION-1.0)
`http://hea-www.harvard.edu/~arots/asc/fits/region.ps`

10. The OGIP Spectral File Format (OGIP/92-007)
`http://legacy.gsfc.nasa.gov/docs/heasarc/ofwg/docs/spectra/ogip_92_007/`

1.4 Data Content Summary

TG data sets generated by the Level 2 processing pipeline shall consist of data files conforming to the FITS format coforming to conventions described in the "ASC FITS File Designers' Guide" (Applicable Document 4, and references therein). These files contain header keyword entries and binary table (BINTABLE) extensions. Following rules outlined in Applicable Document 4, all these files will contain a null primary header followed by a main binary table (the "principal HDU") and auxiliary extensions ("auxiliary HDU").

Any other types of files will either be of types in common use (e.g., PostScript), or fully described here.

1.5 Recipients and Utilization

The primary recipients of TG Level 2 data products, via distribution from the archive, are AXAF observers, who will utilize these data products for scientific data analysis. The CXC may also make use of specific Level 2 data products for instrument calibration, instrument and/or spacecraft monitoring and trends analysis, and validation and verification of the Level 0, Level 1, Level 1.5, and Level 2 software and of the data products themselves.

1.6 Pertinent Relationships with Other Interfaces

Changes to the definition of Level 1.5 data products, as described in Applicable Document 7 may affect the Level 2 data products described in the current document.

1.7 Assumptions and Constraints

1.7.1 Time Dependent Data

For each TG science event run reported in the AXAF telemetry stream, Level 2 processing shall generate a set of product files as described in Section 1.9. The products depend upon possibly time-dependent calibration data for coordinate transformations and region definitions.

1.7.2 Observation Intervals

The natural subdivision of TG processing prior to Level 2 is the Observation Interval (ObI). Each ObI may span several TG science runs, which are the atomic unit of the scientific instrument's telemetry. TG data prior to Level 2 will be processed by ObI. The Level 2 pipeline merges ObIs. Each ObI (or other time-interval) can in principal produce its own Level 2 products, but the pipeline will process merged ObIs.

1.7.3 Un-specified FITS Bintable Columns

Any particular file *may* contain arbitrary additional columns, added at other stages of processing, or by a User. Though they are unspecified, they are permitted. Level 2 software (analysis tools) should ignore them or simply pass them through to output, as directed by Level 2 tool specifications. Their presence should, however, *not* invalidate the product as TG Level 2.

1.7.4 HDU Identifier Keywords

Unless explicitly noted, the `HDUNAME` and `EXTNAME` header keywords will be identical.

1.8 Products Not Covered

TG Level 2 products that are used for maintenance and diagnostic purposes (those that are not supplied to the user for scientific data analysis), or which are generic AXAF Level 2 products, are not currently included within the interface defined by this document.

1.9 Labeling and Identification

The data files generated by the Level 2 processing pipeline shall be assigned external names as defined by the convention specified in "FITS File Names for the AXAF Archive" (Applicable Document 8). The relevant default values for instrument field (`<i>`) are `aciss` or `hrcs`; for data source (`<s>`) is "f" for flight. The appropriate designation for the processing level and sublevel is "2". Level 2 products are listed in the following table:

`*_evt2.fits`	Filtered events	required
`*_pha2.fits`	Binned spectra, Level 2, contents are "Type II 'PHA' or "Type I 'PHA' "	required

(The "`*`" designates an appropriate label sub-string as defined by the CXC FITS file-naming conventions.)

2 Overview of Files

The "ASC FITS Designers' Guide" (Applicable Document 4) defines and lists general header components for the primary header and for all binary table extensions. Since grating data are always obtained with either the HRC or ACIS detectors, file content is also described in detail by the HRC and ACIS Level 1 Interface Control Documents (Applicable Documents 5 and 6). Level 1.5-added content is described in the Level 1.5 ICD (Applicable Document 7).

Events: Level 2 event files are filtered Level 1.5 files.

Spectrum: The basic product is a binned spectrum. This product is based on the OGIP Type II PHA Spectrum (see "The OGIP Spectral File Format", Applicable Document 10. New columns have been added to describe the source, spectrum part, and order. Column names have been taken from the Level 1.5 definition.

Region: The binned spectra are selected from a spatial/spectral region of the Level 1.5 file. The region is given in grating diffraction coordinates (one coordinate in the dispersion direction, and one in the cross-dispersion direction; see Applicable Documents 1 and 7). The spatial/spectral extraction region mask is by default encoded as a region extension (see "FITS REGION Binary Table Design (ASC-FITS-REGION-1.0)", Applicable Document 9) in the Level 2 FITS file.

3 Event Files (*_evt2.fits)

Event Level 2 ("`*evt2.fits`") files have the same structure as grating Level 1.5 ("`*evt1a.fits''`) files, the only difference being in the number of rows. Filtering is done to remove bad events.

4 Spectral Histogram Files (*_pha2.fits)

CXO binned grating spectrum files are stored as "PHA" files. Here, "PHA" does not refer to the content, but to the form of the file, as defined by OGIP conventions, originally conceived for spectral files from a Pulse Height Analyzer (which produced signals pulse-height bins with Pulse Height Amplitudes).

During Level 1.5 processing, event coordinates undergo several transformations. Given a zero-order centroid in sky coordinates, a region angle, and region width, events within each region are given several new coordinates. Proper interpretation of the spectrum requires consistent selection on several coordinates. These coordinates are carried over into the Level 2 spectrum file as attributes of the spectrum.

TG_SRCID is the source number, as output from the detection algorithm. A *TG_SRCID* of 0 means background — the photon has not been associated with a detected source. It is permitted to store binned spectra from multiple sources in one Type II file.

TG_PART identifies the region of the spectrum of which the photon is a part. This can have only specific values as follows:

- **0:** zero order;
- **1:** HEG part of the spectrum;
- **2:** MEG part;
- **3:** LETG photon;
- **99:** background.

TG_M: The diffraction order, if resolved. This is a small integer, not likely to be of absolute value greater than 10 for HETG/ACIS-S. The value, 99, is used as a flag for "unresolved" or background photons.

For LETGS photons (detector is HRC, *TG_PART* is 3), *TG_M* will be either $+1$ or -1, since HRC cannot resolve the orders via a pulse-height value.

The physically meaningful geometric limit set by the ACIS-S array with HETG is about ± 62. This is for a 10 keV photon observed with the aim-point at one end of the ACIS-S array, and the detected photon at the other end. It is not a likely scenario, but is used to define allowed physically conceivable data ranges.

4.1 HDU Components

The following table describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the principal HDU.

HDU	HDU Type	EXTNAME	CONTENT	HDUCLASS	Description
0	PRIMARY	N/A	N/A	N/A	NULL
1 (*)	BINTABLE	SPECTRUM	SPECTRUM	OGIP SPECTRUM TOTAL COUNT	Binned spectra, vs order vs source, grid, and ancillary information. A Type II file is the default; Type I is supported.
2	BINTABLE	REGION	TGMASK2	ASC REGION TG	Spectral-spatial region over which the spectrum was binned.

The structure of the HDUs, as specified by the ASC FITS Guide (Document 4), is

- Null Primary HDU:

  image mandatory
  null configuration control
  short timing
  short observation

- Principal table HDU:

  bintable mandatory
  table coordinates
  full configuration control
  full observation
  full timing

- Auxiliary table HDU:

  bintable mandatory
  table coordinates
  short configuration control
  short timing
  short observation

4.1.1 Naming Type I and II PHA Files

Type II PHA files are named according to the CXC FITS guidelines (Document 8), and are of type (“`<c>`”) `pha` and processing level (“`<l>`”) 2. For Type I files, the optional discriminator field (“`<f>_`”) may be used to indicate the source identifier, spectrum part, and order.

4.2 Column Specifications: Type II PHA

The contents of the FITS columns of the binned spectrum extension are given in the following tables. These generally conform to the “OGIP Type II PHA” definition (See Document 10), with some additions appropriate for CXO grating spectra. Some columns are optional, but are listed for complete compatibility with the OGIP standard; those that probably won't be used are in a separate table.

Columns which are constant may be promoted to header keywords. Some are mutually exclusive; for example, if a `BG_COUNTS` array column is present, then `BACKFILE` does not need to be specified. The primary point of following the OGIP Type II specification is to maintain compatibility with XSPEC.

The length of the vector columns (specified by `TFORM`n) such as for `COUNTS` is given in the table as n, which is determined by processing software. Default lengths for LETGS are 16384, and for HETGS, 8192.

Note: Real-valued columns are given as `TFORM` type "D" or "E", but these should be interchangeable as far as file-reading software is concerned. There is no strict requirement for single or double precision quantities, and the format should be considered a valid PHA file in either case.

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
SPEC_NUM		1I	1	*	N/A	0	Spectrum number (arbitrary running index).
ROWID		64A	N/A	N/A	N/A	NONE	Arbitrary string identifier
TG_M		1I	−62	62	N/A	99	Diffraction order (m)
TG_PART		1I	0	99	N/A	N/A	Spectral component (HEG, MEG, LEG, HESF parts)
TG_SRCID		1I	1	*	N/A	0	Source ID, output by detect.
X	pixel	1E	0.5	*	N/A	NaN	Source sky-x position
Y	pixel	1E	0.5	*	N/A	NaN	Source sky-y position
CHANNEL		nI	1	n	1	0	Vector of spectral bin numbers.
BIN_LO	angstrom	nD	0.0	400.0	1.0E-04	NaN	Bin boundary, "left" edge.
BIN_HI	angstrom	nD	0.0	400.0	1.0E-04	NaN	Bin boundary, "right" edge
COUNTS	count	nI	0	*	1	-1	Counts array (a spectrum).
BACKSCAL	degrees	nE	0	360	N/A	NaN	Source region `BACKSCAL`, or "area" (really a cross-dispersion width, for grating spectra).
STAT_ERR	count	nE	0.0	*	N/A	NaN	Statistical uncertainty on COUNTS (optional)
BG_COUNTS	count	nI	0	*	1	-1	Background counts array.
BG_AREA	degrees	nE	0	360	N/A	NaN	Background region `BACKSCAL` (or "area"; width in cross-dispersion direction.)
BG_ERR	count	nE	0.0	*	N/A	NaN	Background statistical uncertainty on BG_COUNTS column (optional)
QUALITY		nI	0	5	N/A	N/A	Quality flag
GROUPING		nI	-1	1	N/A	255	Grouping vector
ANCRFILE		64A	N/A	N/A	N/A	NONE	Ancillary response file name (ARF).
RESPFILE		64A	N/A	N/A	N/A	NONE	Grating Redistribution (LSF) file name (RMF).
BACKFILE		64A	N/A	N/A	N/A	NONE	Background file name.
FLUX	phot/s /cm**2 /bin	nE	0.0	N/A	N/A	NaN	Flux
FLUX_ERR	(same as FLUX)	nE	0.0	N/A	N/A	NaN	Uncertainty on flux.

Some columns are maintained for back-compatibility with `XSPEC`, or other software which relies on the standard OGIP spectral file specification. The columns (or keywords) which will probably not be used are given in the following table.

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
CORRFILE		64A	N/A	N/A	N/A	none	Correction file name.
CORRSCAL		1E	0	N/A	N/A	NaN	Correction scale factor.
SYS_ERR	count	nE	0.0	TBD	N/A	NaN	Systematic uncertainty on count vector column.
AREASCL		1E	0.0	N/A	N/A	NaN	Area scaling factor, if ANCRFILE needs a correction.

Table notes:

"N/A" means "Not Applicable". The "TNULL" value of "NaN" stands for the IEEE "Not A Number" (which is not actually encoded into the header, but is implicit in the FITS convention). These are the columns defined by the OGIP Type II specification, but which are unlikely to be needed for AXAF grating spectra.

* For items with no physical legal maximum, the TLMAX value is limited by the data-type to max(TFORM).

Additional descriptions of table columns:

SPEC_NUM Required. Spectrum number.

ROWID Optional; Arbitrary string identifier

TG_M Required; diffraction order (m)

TG_PART Required; Spectral component (HEG, MEG, LEG, ...)

TG_SRCID Required; source ID. If the Level 1.5 file has been split by source, then this will be a constant for the Level 2 file, and it will become a header keyword (`TG_SRCID` $= n$).

X,Y give the zero order source centroid, which is needed when computing the grating ARF.

CHANNEL Required; array of spectral bin numbers.

BIN_LO Required; Bin boundary, low coordinate. By default, the bin units are Ångstroms. Default grids for all gratings start at 1.0 Å. Default step sizes are 0.0025, 0.0050, 0.0125 Å for HEG, MEG, and LEG, respectively. The default array lengths are 8192 for ACIS-S and 16384 for HRC-S.

BIN_HI Required; Bin boundary, high coordinate. Default units are Ångstroms.

COUNTS Required; Counts array (a spectrum).

STAT_ERR Optional; statistical uncertainty ("error") on count column. If the keyword POISSERR exists and has the value `T`, then this column may not be present. (Note that this condition applies to all rows containing counts-type data.)

BACKSCAL Scaling array corresponding to `COUNTS`, which gives the cross-dispersion extraction width for each bin of the source region extraction. (If constant, could be a header keyword). Revised in CIAO 4, for `tgextract2`.

BG_COUNTS Optional; background count vector. Mutually exclusive with the BACKFILE column. Introduced in CIAO 4 with `tgextract2`, and replaces the deprecated `BACKGROUND_UP` and `BACKGROUND_DOWN` columns.

BG_ERR Optional; statistical uncertainty ("error") on `BG_COUNTS` column. If the keyword POISSERR exists and has the value `T`, then this column may not be present. (Note that this condition applies to all rows containing counts-type data.) Introduced in CIAO 4 (`tgextract2`).

BG_AREA Background-scaling array corresponding to `BG_COUNTS`, which gives the cross-dispersion extraction width for each bin of the background extraction. (If constant, could be a header keyword). Introduced in CIAO 4 (`tgextract2`).

QUALITY Optional; Quality flag. The interpretation is as follows:

0: Good;

1: bad – never use;

2: dubious, recommend ignoring;

5: user-specified as bad;

Other values: spare.

If all values are 0, then this should be promoted to a header keyword (`QUALITY=0`) and the column deleted (note: this must be true for *all* rows).

GROUPING Optional. Grouping vector. If the data are un-grouped, then a header keyword is set (`GROUPING = 0`) and the column is not present. Otherwise, the interpretation is:

+1: channel starts a new group;

−1: channel is part of a continuing group;

0: grouping is undefined.

(Note that if *any* row is grouped, then all rows must have the grouping vector present.)

FLUX Optional; Flux; Default units are photons $\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{bin}^{-1}$. Flux is determined by dividing the count-rate by a suitable effective area.

FLUX_ERR Optional. Uncertainty on flux. Only present if the FLUX column is defined.

ANCRFILE Required (but default is "NONE"); Ancillary response file name (ARF). This is the output of `mkgarf`.

RESPFILE Required (but default is "NONE"). Redistribution file name (RMF). This is a redistribution from wavelength to position (ouitput of `mkgrmf`).

BACKFILE Optional; background file. Mutually exclusive with the BACKGROUND column.

CORRFILE Optional; "correction" file

CORRSCAL Optional; "Correction" scale factor

SYS_ERR Optional; Systematic uncertainty on count vector column. If present, these values may get added in quadrature to the statistical errors by processing software (such as XSPEC).

AREASCL This is an optional area-scaling factor. It is most likely a constant and equal to 1.0, and so should be a header keyword (if present at all). It is only for XSPEC compatibility.

4.3 Column Specifications: Type I PHA

The Type I PHA format is supported for storage of single-order spectra and for back-compatibility with existing software. The format follows straightforwardly from that of the Type II file: an array column of `TFORM =` n`D` becomes a column vector having n rows of `TFORM = 1D`. Other array columns in the row become column vectors. Other scalar columns become header keywords.

4.4 Keywords Describing Coordinate Systems

All columns either need no coordinate system, or are already in physical units. There are no `TCRPX`n`,` `TCRVL`n, etc., keywords required.

4.5 Grating Spectral Region Definitions

The Level 2 binning region is specified by shapes in grating coordinates, which are a sub-selection of the Level 1.5 sky (spatial) filtering region (but in transformed coordinates).

The generic definition of an CXC FITS region is given in the "FITS REGION Binary Table Design" (Applicable Document 9). The region HDU will be a single `REGION` auxiliary extension, whose header is comprised of these components:

mandatory `REGION`-content header,
table coordinate system and ranges,
short configuration control,
short timing, and
short observation information.

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	Comment
SPEC_NUM	-	1I	1	*	Spectrum number, which points the the row in the SPECTRUM extension to which the region on this row applies.
ROWID	-	64A	N/A	N/A	Source or a background region? (`SOURCE | BACKGROUND`)
SHAPE	-	16A	-	-	Shape of region: must be `BOX` (or `POLYGON` starting with CIAO 4) for grating Level 2.
TG_R	deg	1*E*	-360.	360.	Dispersion coordinate vector for `SHAPE`. (optional; one of TG_R or TG_LAM must be present.);
TG_LAM	angstrom	1*E*	0	400.	Dispersion coordinate vector for `SHAPE`. (optional; one of TG_R or TG_LAM must be present.);
TG_D	deg	1*E*	-2.	2.	Cross-dispersion coordinate vector for `SHAPE`.
R	N/A	2*E*	0	400	Radius vector for `SHAPE`. The interpretation of coordinates and units depends upon the `SHAPE`.
ROTANG	deg	1*E*	-360	360	Rotation angle for SHAPE, in degrees (usually 0.0 for grating Level 2).
TG_PART	-	I	1	*	Key to grating type.
TG_SRCID	-	I	1	*	Source identification number.
TG_M	-	I	-62	62	Diffraction order.
COMPONENT	-	I	0	7	Component number that `SHAPE` belongs to (default is 1). Equivalent to `TG_PART`.

The interpretation of the `COMPONENT` value is shown in this table:

GRATING	TG_PART	Meaning
HETG		
	1	HEG arm
	2	MEG arm
LETG	3	LEG arm

The interpretation of the coordinate vectors for grating region shapes, as given in the FITS region specification (Applicable Document 9) is:

`BOX:` First element of each X and Y vectors specify the center of a rectangle. The first element of `ROTANG` specifies counter-clockwise rotation of the rectangle with respect to X and Y axes. The center of the rotation is the center of the rectangle (given by X, Y). ROTANG is always zero for this specification.

Other elements (if present) of X, Y are undefined. The first two elements of R specify the full-widths of X and Y, respectively.

`POLYGON` (Introduced in CIAO 4, `tgextract2`) Values are interpreted as vertices of a polygon. The polygon is closed by a repeat of the first point.

A schematic of a diffraction coordinate binning region sky coordinates is shown in Figure 4.5.

The diffraction coordinates must be tied to the region generic "X" and "Y" tokens so that the `SHAPE` and `R` columns can be properly interpreted. The mechanism for this is via "Data Model" keywords:

```
MFORMn  = 'TG_LAM, TG_D'       / wavelength vs cross-disp angle
MTYPEn  = 'wavpos '           / Wavelength-vs-position coords
```

where n is the n^{th} coordinate pair (and here would be 1, since there are no others). These keywords specify that `TG_LAM` is to be treated as X and `TG_D` is to be treated as Y, according to the region file specification.

The `MFORM, MTYPE` *pair above is the format for the output binning region of a grating PHA file.*

There are other coordinates which could be used for the dispersion, such as `TG_R` and `TG_MLAM`. As an example (which is used in the CALDB "bow-tie" binning region for LETGS, `letgD1999-07-22regN0002.fits`) the header coordinate keywords would become:

```
MFORMn  = 'TG_R, TG_D'       / wavelength vs cross-disp angle
MTYPEn  = 'dispang'          / Wavelength-vs-position coords
```

An example of this type is the *intput region* format for binning grating PHA files (via `tgextract`).

4.6 Volume, Size, and Frequency Estimates

A default-extraction HETGS file (the largest case; orders -3 to 3, HEG and MEG, with backgrounds) is about 3 MB. There is one file per observation.

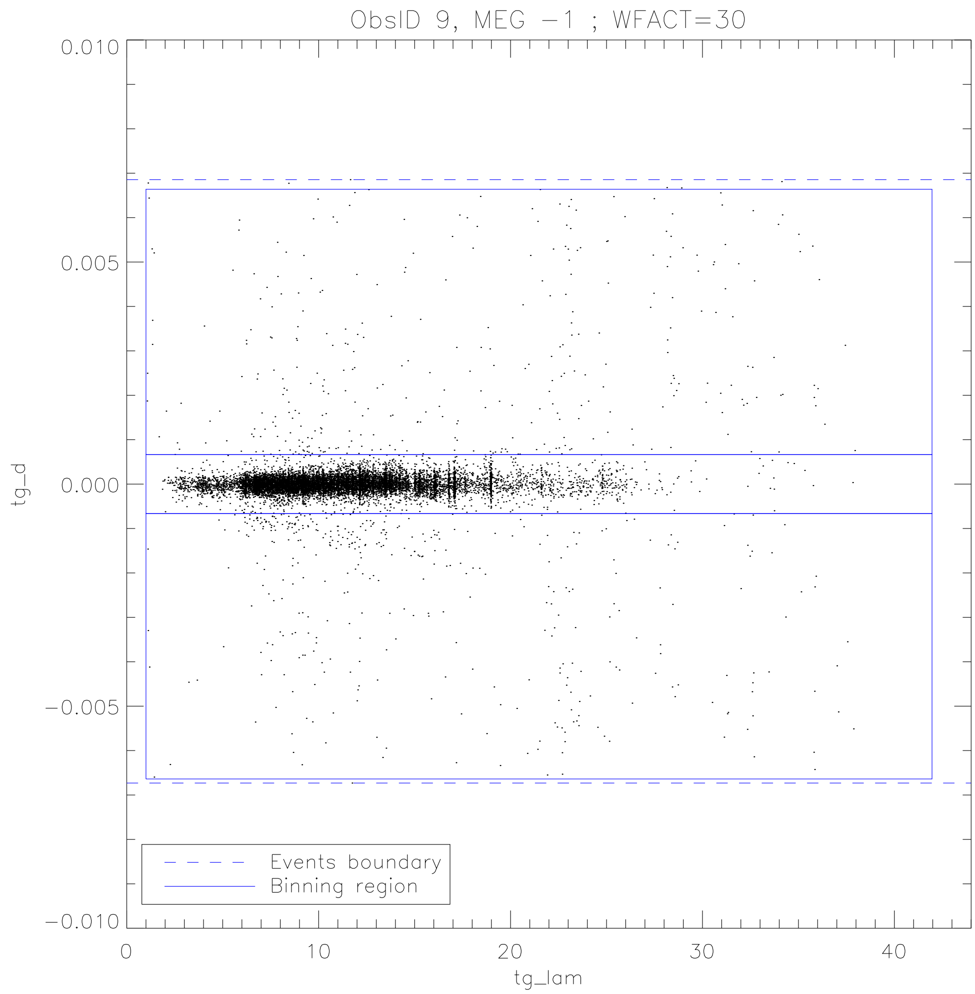

Figure 1: *This is an example of HETG events in grating coordinates showing the source events (centered on tg_d = 0). The narrow central rectangle is the source-binning region, and the upper and lower wide rectangles give the background binning regions.*